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(54) Method of manufacturing a jet  
 nozzle plate for an ink-jet printing  
 head

(57) A plate 1 of chemically etchable  
 material is first provided with a bore 2  
 for each nozzle, the bore having a  
 diameter larger than the desired  
 internal diameter of the ultimate jet  
 nozzle. Recesses 4 are then formed  
 and then the whole of the plate  
 including the wall of each bore is  
 covered with a layer 7 of chemically

deposited etch-resistant material.  
 Subsequently the etch-resistant layer  
 on the raised portion of the plate  
 around each bore 2 is removed by  
 grinding the front side of the plate  
 down to the level, (see dotted line) of  
 the etch-resistant layer 7 in the  
 recesses 4. The material of the plate  
 exposed by the grinding is then  
 removed by etching to leave the etch-  
 resistant layer 7 on the wall of each  
 bore 2 projecting as a cylindrical tube  
 8 from the front side of the plate to  
 form a jet nozzle.

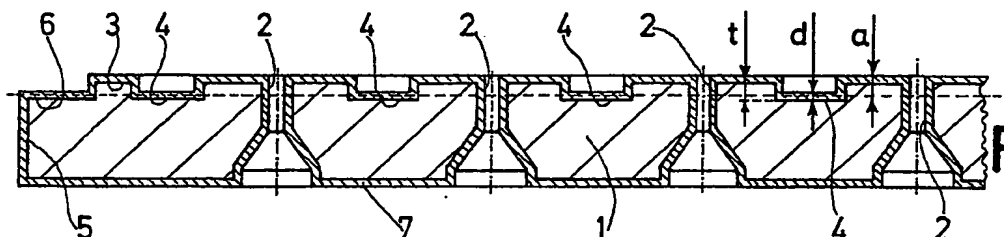


Fig. 4

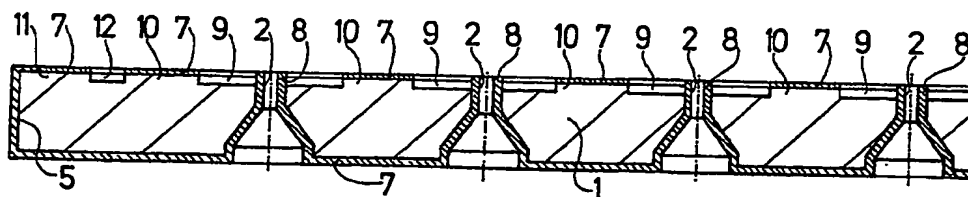


Fig. 6

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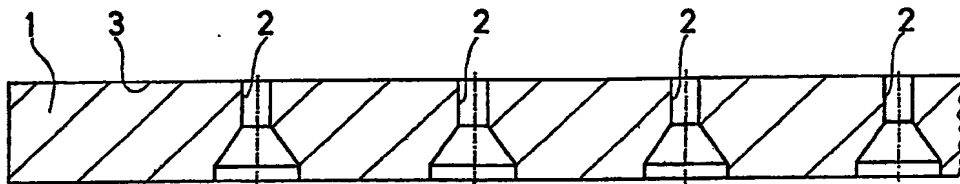


Fig.1

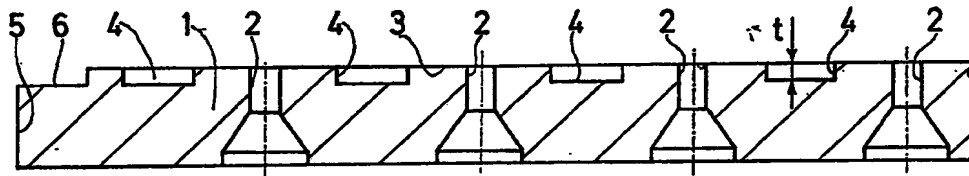


Fig.2

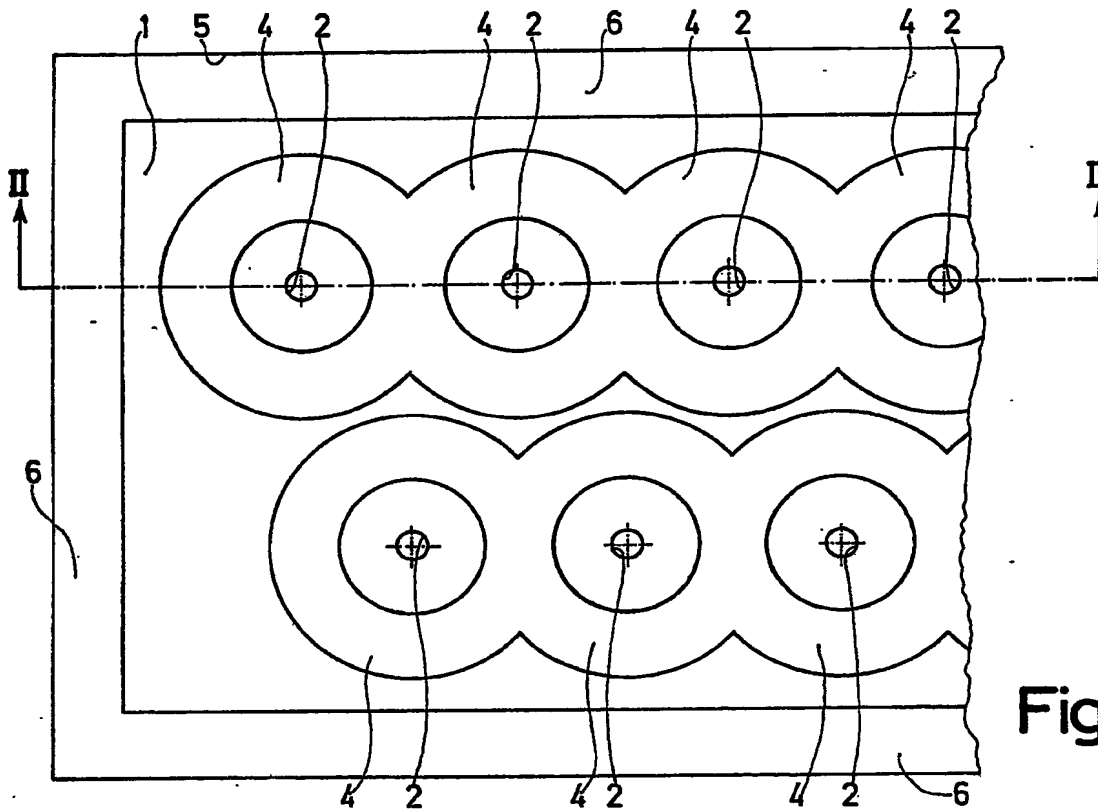


Fig.3

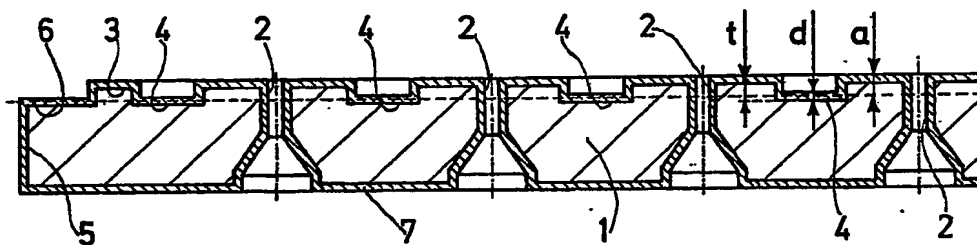


Fig.4

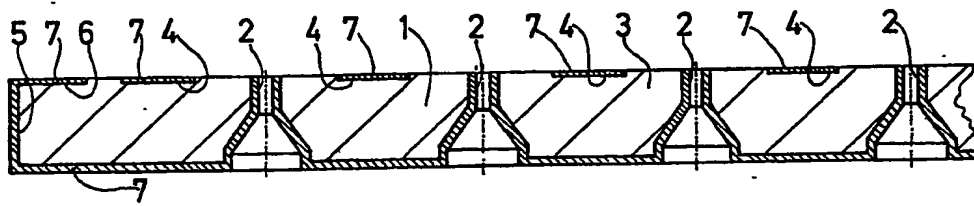


Fig. 5

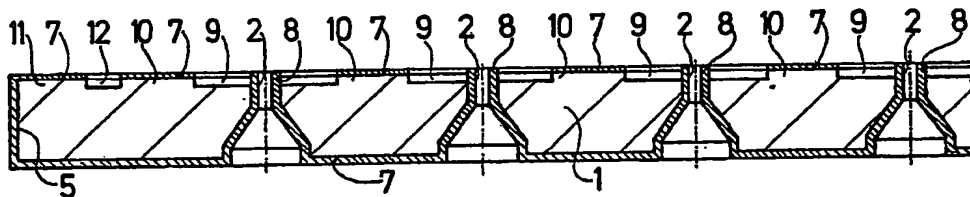


Fig. 6

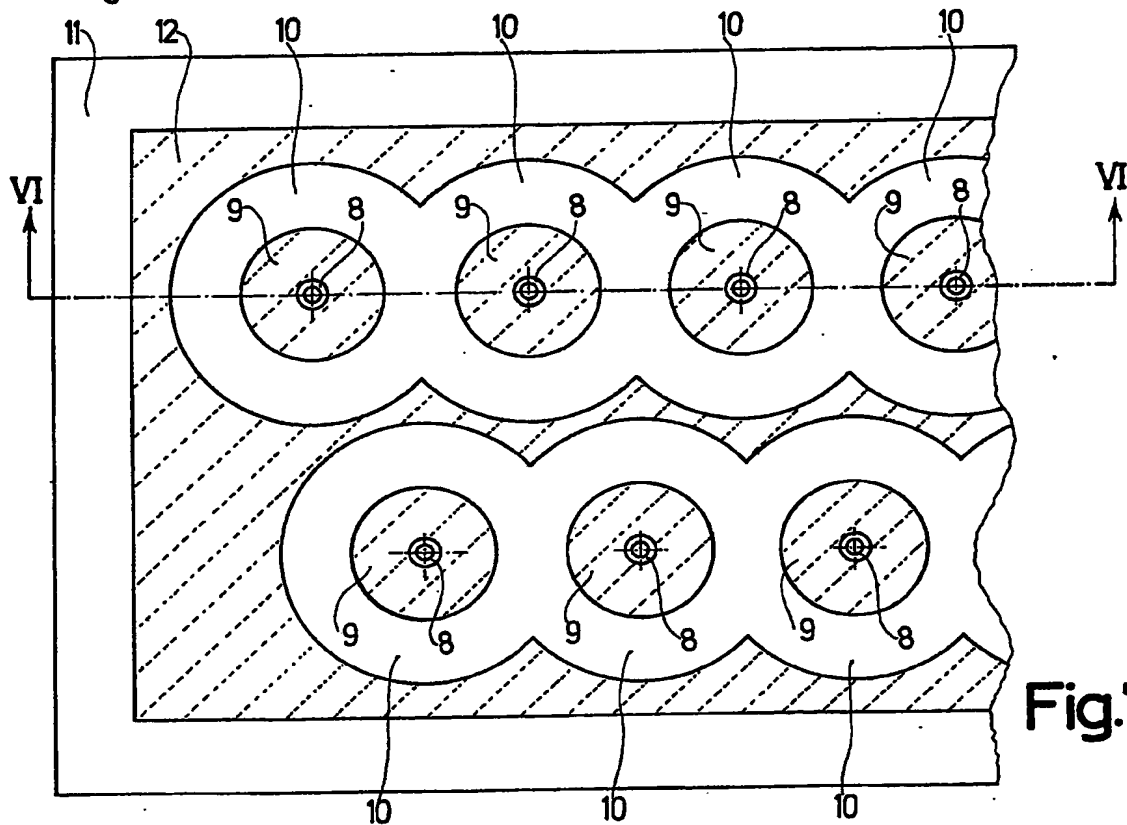


Fig. 7

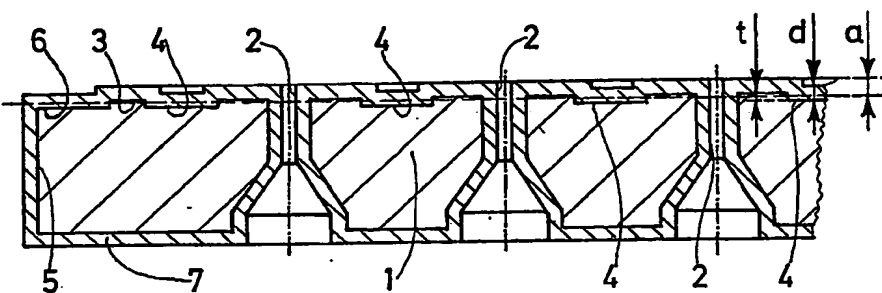


Fig. 8

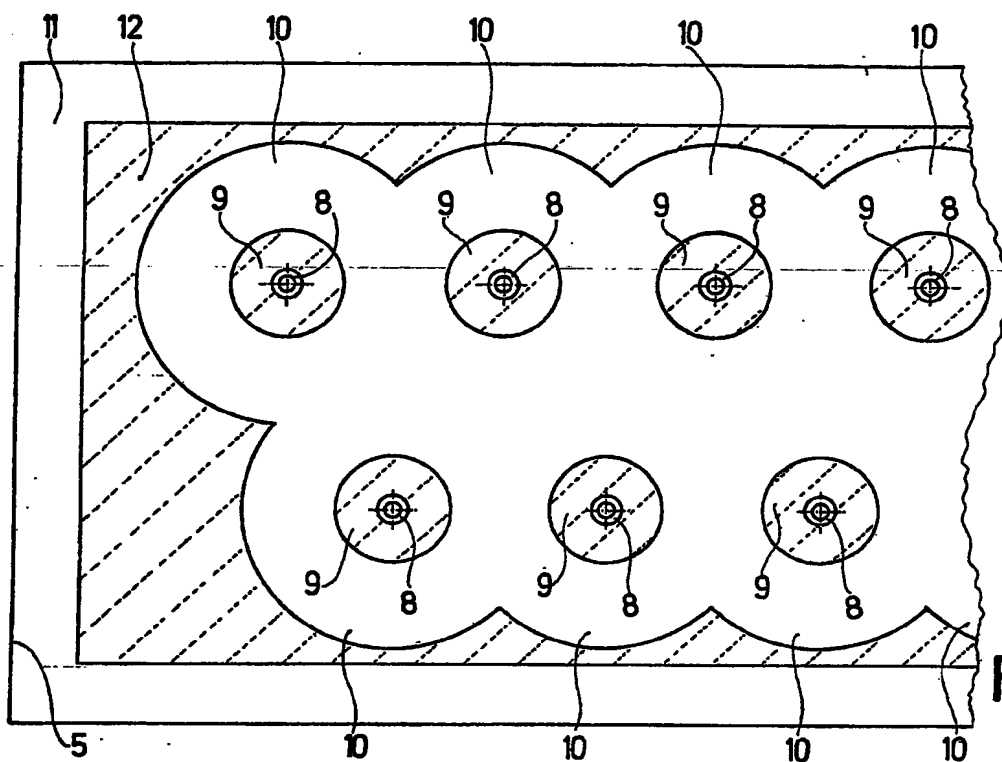


Fig.9

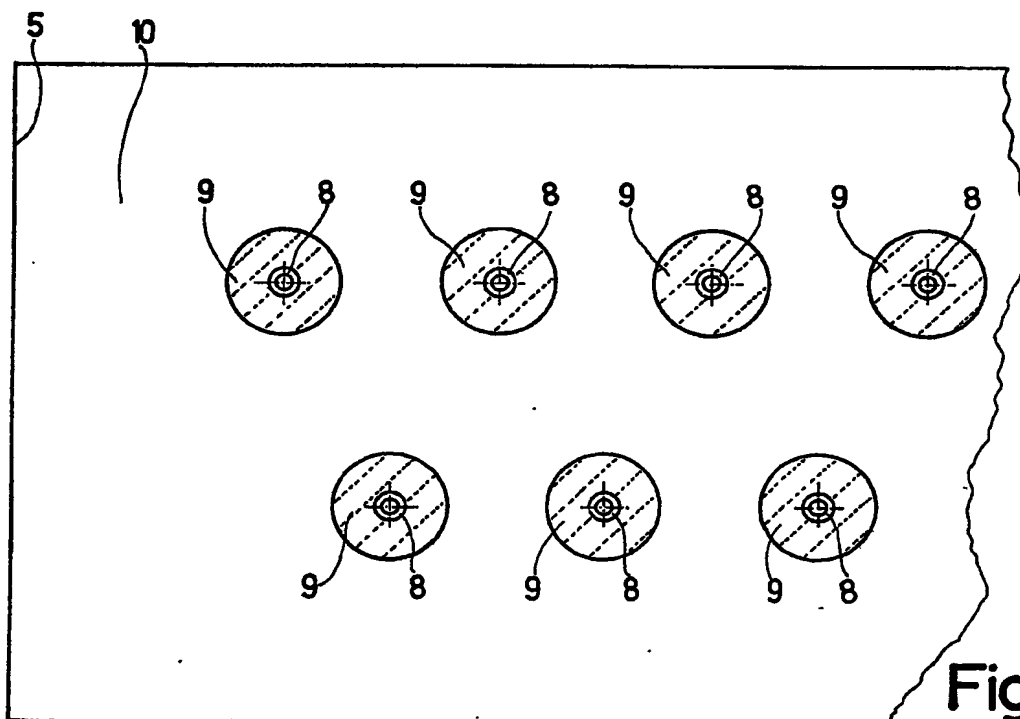
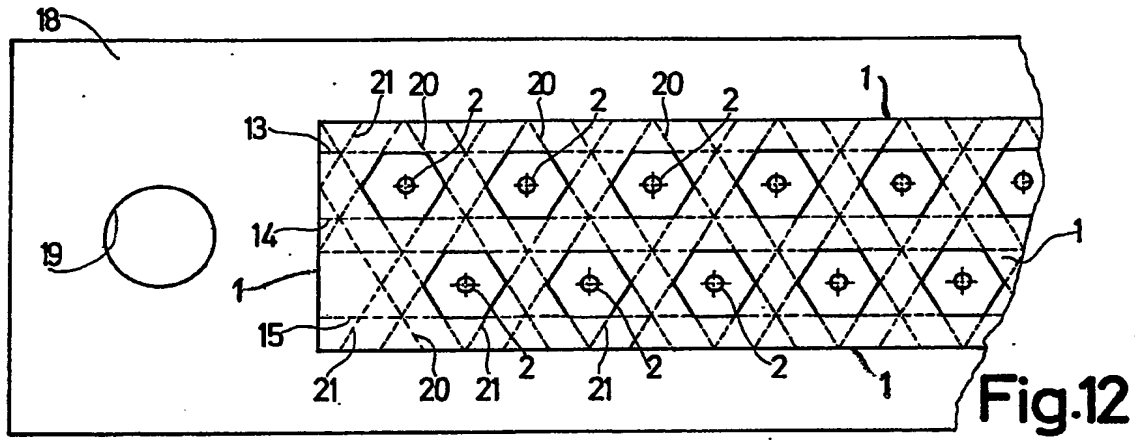
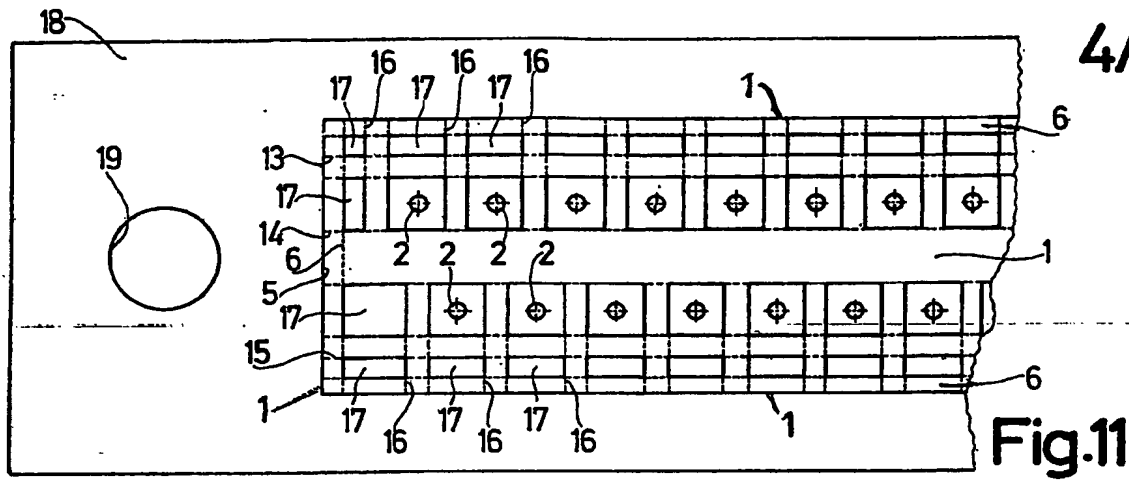


Fig.10

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## SPECIFICATION

## Method of manufacturing a jet nozzle plate for an ink-jet printing head

The invention relates to a method of manufacturing a jet nozzle plate for an ink-jet printing head, which plate comprises a jet nozzle having a given internal diameter.

IBM Technical Disclosure Bulletin, Vol. 15, No. 9, pages 2845 and 2846, discloses a method of manufacturing such a jet nozzle plate, in which a base plate from which the jet nozzle plate is to be formed and which is made of a chemically etchable material is first provided with a bore having a diameter larger than the desired internal diameter of the ultimate jet nozzle, and a wire is concentrically inserted in the bore, the diameter of said wire corresponding to the desired internal diameter of the ultimate jet nozzle, after which the whole of the base plate including the wall of the bore is covered with a layer of etch-resistant material which is chemically deposited on the plate. The wire is then removed by etching so that the jet nozzle is freed. A given length of the wire projects from the bore, so that etch-resistant material is also deposited on this projecting part of the wire and a jet nozzle is formed which consists of a tube whose free end projects from the jet nozzle plate. A method of this kind is not easy to perform, particularly in view of the centering of the wire in the bore.

For the manufacture of a jet nozzle plate in which a jet nozzle is formed by a tube whose free end projects from the jet nozzle plate, it may be stated that even though favourable properties are thus obtained as regards the ejection of droplets of ink from such a jet nozzle plate, it is difficult to cap the jet nozzle exactly with a capping device when the jet nozzle is not in use, for example, in the rest condition of the ink-jet printing head, in order to prevent drying of the ink in the jet nozzle and hence clogging of the nozzle so that it can no longer be used. This difficulty arises *inter alia* because the capping device, customarily consisting of a slightly elastic cushion, is not arranged exactly flat against the end face of the tube but is curved over this end, so that it does not completely cover the jet nozzle. In this respect German Auslegeschrift 23 62 576 has already proposed an embodiment of the jet nozzle plate in which an annular trough is provided around a jet nozzle, said trough being adjoined by a land having a plane surface which is situated at the same level as the end face of the jet nozzle, which itself is also tubular. However, said German Auslegeschrift 23 63 576 does not describe how such a jet nozzle plate can be efficiently manufactured.

According to the present invention there is provided a method of manufacturing a jet nozzle plate for an ink-jet printing head, which plate comprises a jet nozzle having a given internal diameter, wherein a base plate from which the jet nozzle plate is to be formed and which is made of a chemically etchable material is first provided

with a bore which extends through the base plate and of which at least a portion that opens out of one side of the plate is cylindrical and has a diameter larger than the desired internal diameter of the ultimate jet nozzle, material is then removed from said one side of the base plate by milling so as to leave on said side of the base plate a portion which adjacently surround the bore and is raised with respect to the adjoining portion of said side of the base plate, the whole of the base plate including the wall of the bore is subsequently covered with a layer of etch-resistant material which is chemically deposited on the plate to a thickness equal to half the difference between the diameter of said cylindrical portion of the bore and the desired internal diameter of the ultimate jet nozzle, after which the etch-resistant layer is removed from at least the top of the raised portion on said one side of the base plate by grinding in a plane perpendicular to the axis of the bore to a depth which at least equals the thickness of said layer but which is smaller than the sum of the thickness of the layer and the depth to which material was removed from said one side of the base plate by milling, and finally material of the base plate surrounding the bore and exposed by the grinding is removed by etching to leave the etch-resistant material which was deposited on the wall of said cylindrical portion of the bore projecting as a cylindrical tube from said one side of the base plate to form the jet nozzle, the tube being surrounded by a trough formed in said one side of the base plate by the etching.

Preferably, the grinding is continued until the etch-resistant layer on that part of said one side of the base plate from which material was removed by milling has been partially ground down. This part of the base plate, with the etch-resistant layer thereon, is then left by the subsequent etching process as a land on said one side of the base plate, the top surface of the land lying in the same plane as the end face of the tube forming the jet nozzle. The top surface of the land consequently provides an accurate supporting surface for a capping device for the jet nozzle plate.

The removal of material from said one side of the base plate by milling may form an annular recess in said side of the plate, which recess surrounds and is spaced from the bore in the base plate. The recess can be formed simply and accurately by means of an end-milling cutter.

Alternatively, the removal of material from said one side of the base plate by milling may be effected by milling straight grooves in said side of the plate, the grooves intersecting one another so as to form around the bore in the base plate and spaced therefrom a recess in the form of a channel of polygonal shape in said side of the base plate. The grooves may be formed by means of a side-milling cutter.

Material may be removed from said one side of the base plate by milling to a depth which is smaller than the thickness of the etch-resistant layer subsequently deposited thereon. Because the amount by which this side of the base plate is

subsequently ground down must be at least equal to the thickness of the layer but smaller than the sum of the thickness of this layer and the depth of which material was removed from said side of the base plate by milling, grinding may be comparatively critical if the milling depth is small. Preferably, therefore, the removal of material from said one side of the base plate by milling is carried out to a depth which is greater than the thickness of the etch-resistant layer subsequently deposited on the base plate, the subsequent grinding being continued until the etch-resistant layer on that part of said one side of the base plate from which material was removed by milling has been partially ground down. The amount of grinding is thus greater, so that the grinding operation can be better controlled.

In those embodiments in which the removal of material from said one side of the base plate by milling leaves in this side of the plate a recess surrounding and spaced from the bore in the plate, a rebate may be milled in said one side of the base plate around the edge thereof prior to the deposition of the layer of etch-resistant material, the rebate having the same depth as the recess surrounding the bore in the base plate. This rebate results in the production of an additional land on the base plate to provide a further supporting surface for a capping device.

For manufacturing a jet nozzle plate having a plurality of jet nozzles the base plate may be formed with a corresponding plurality of said bores, and around each bore at a distance therefrom a recess may be milled in said one side of the base plate so as to leave on this side of the plate a raised portion adjacently surrounding the respective bore, the recess being formed so as to merge with one another. This results in the formation of a continuous land on the base plate to provide a continuous supporting surface for a capping device.

To obtain the maximum supporting surface for a capping device, material may be removed by milling from the whole of said one side of the base plate except for the portion surrounding the bore.

Some embodiments of the invention will now be described in detail with reference to the accompanying drawings, in which:

Fig. 1 is a sectional view of a part of a base plate formed with a plurality of bores for jet nozzles,

Fig. 2 is a sectional view taken on the line II—II in Fig. 3, showing the base plate of Fig. 1 formed with recesses around the bores,

Fig. 3 is a front elevation of part of the base plate of Fig. 2,

Fig. 4 is a sectional view showing the base plate of Fig. 2 after the deposition of the etch-resistant layer,

Fig. 5 is a sectional view showing the base plate of Fig. 4 after the grinding of the front side thereof,

Fig. 6 is a sectional view taken on the line VI—VI in Fig. 7, showing the base plate of Fig. 5 after the etching which produces the finished jet

nozzle plate,

Fig. 7 is a front elevation of the jet nozzle plate shown in Fig. 6,

Fig. 8 is a view similar to Fig. 4, showing a base plate formed with recesses whose depth is smaller than the thickness of the etch-resistant layer,

Fig. 9 is a front elevation of part of a finished jet nozzle plate in which the lands surrounding the troughs around the jet nozzles all merge with one another to form a continuous surface for supporting a capping device.

Fig. 10 is a view similar to Fig. 9, showing a finished jet nozzle plate in which one continuous land surrounding the troughs around the jet nozzles extends as far as the edges of the plate,

Fig. 11 is a view similar to Fig. 3, showing a base plate in which recesses in the form of channels of rectangular shape are formed around the bores in the plate by milling a pattern of straight intersecting grooves in the front side of the base plate, and

Fig. 12 is a view similar to Fig. 11, showing a base plate in which a pattern of straight intersecting grooves is milled in the front side of the base plate such as to leave raised portions of hexagonal shape surrounding the bores in the plate.

The principle of the method of manufacturing a jet nozzle plate in accordance with the invention will be described in detail hereinafter with reference to Figs. 1 to 7. Fig. 1 shows part of a base plate 1 for a jet nozzle plate, which base plate consists of a chemically etchable material, preferably brass. For this embodiment it is assumed that the jet nozzle plate is to comprise two parallel rows of jet nozzles, the jet nozzles in one row being staggered with respect to the jet nozzles in the other row and each row comprising, for example, twelve jet nozzles. Obviously, it is alternatively possible to provide more than two rows of jet nozzles or only one row of jet nozzles, and the number of jet nozzles may also be different, even to the extent of having a single jet nozzle. This is completely dependent on how the characters are formed by means of the ink-jet printing head for which the jet nozzle plate is intended. To form the individual jet nozzles, the base plate 1 is first provided with bores 2 which are cylindrical at the front 3 of the base plate, widen in a conical manner towards the rear of the plate and finally become cylindrical again. It has been found that such a shape, which is known *per se*, is advantageous with respect to the ultimate configuration of the ink-jet nozzles and the connection of the ink supply ducts to the individual jet nozzles of the jet nozzle plate (which is irrelevant to the invention). However, it is also possible to give the bores 2 a wholly cylindrical shape. The diameter of the bores 2 is larger than the internal diameter of the ultimate jet nozzle. This offers the advantage that it simplifies the formation of the bores 2 since the internal diameter of a finished jet nozzle is usually very small, for example, of the order of 0.05 mm.

The next step in the manufacture of the jet

nozzle plate is the milling of a recess 4 around each bore 2 in the front side 3 of the base plate 1, the recess being concentric with and spaced from the bore, as shown in Figs. 2 and 3. The recesses 4 in this embodiment are of annular shape and can be very accurately formed by means of an end-milling cutter. The inner and outer diameters of the recesses in this embodiment are so chosen that adjacent recesses in each row merge and open into one another. It is alternatively possible to give the recesses diameters such that adjacent recesses do not open into one another, each bore 2 then being surrounded by a recess which has the shape of a closed circular ring. It has been found that the inner diameter of the recesses should preferably amount to eight times the internal diameter of the ultimate jet nozzles to ensure sufficient freedom around the tubes which, as will be described later herein, form the finished jet nozzles. The outer diameter of the recesses is dependent on the distance between adjacent bores or finished jet nozzles, which distance may be of the order of, for example, 0.5 mm. The depth  $t$  of the recesses 4 may be of the order of 0.04 mm when the other dimensions have the values given above. It has also been found that for reasons which will be explained later herein, a rebate 6 should preferably be milled in the front side of the base plate around the edge thereof to the same depth as the recesses 4 surrounding the bores 2.

The whole of the base plate 1, including the walls of the bores 2, is subsequently covered with a layer 7 of an etch-resistant material of a kind which can be deposited on the plate 1 by a chemical process, for example, nickel. The choice of the thickness  $d$  of this layer is governed by the fact that the internal diameter of the ultimate jet nozzles will be determined by the thickness of this layer. The thickness of the layer is consequently made equal to half the difference between the diameter of the front cylindrical portions of the bores 2 and the desired internal diameter of the ultimate jet nozzle. A value of approximately 0.03 mm may be chosen for the thickness of the layer 7. The base plate 1 is now in the condition shown in Fig. 4. As can be readily seen, the depth  $t$  of the recesses 4 in this embodiment is chosen so that it exceeds the thickness  $d$  of the layer 7.

In the next step, the front 3 of the base plate 1 is ground down by an amount  $a$  which at least equals the thickness  $d$  of the layer 7 but which is smaller than the sum of the thickness  $d$  of the layer 7 and the depth  $t$  of the recesses 4. In this embodiment, this amount  $a$  is so chosen within the said limits that during the grinding down of the front of the base plate, the portions of the layer 7 that cover the bottoms of the recesses 4 and the rebate 6 are also slightly ground down as shown in Figs. 4 and 5. Thus, around each bore, and between the recesses 4 and the rebate 6, material of the base plate 1 is exposed, the originally continuous layer 7 of etch-resistant material thus being divided into separate layers 7. Because grinding is continued until the layers on the

bottoms of the recesses 4 and the rebate 6 are also ground down slightly, it is ensured that there are no raised edges on these layers, so that the front of the base plate forms a completely flat surface.

Finally, at the front of the base plate 1, exposed material of the plate is removed by etching, leaving the etch-resistant material of the remaining layers 7 intact. This leaves the layers 7 in the bores 2 projecting from the base plate 1 as free cylindrical tubes 8, each of which forms a jet nozzle, as shown in Figs. 6 and 7. As a result of the removal of material of the base plate 1 around each of the tubes 8, each of these tubes is surrounded by an annular trough 9 which is in turn surrounded by a land 10 having a plane surface which has not been affected by the etching operation since it is formed by a layer 7 of etch-resistant material. Accordingly, each land 10 consists of the material of the base plate at its base and of the material of the layer 7 at its top. The outer diameter of the troughs 9 corresponds to the inner diameter of the recesses 4. A land 11 also extends around the edge 5 of the base plate on the front side thereof as a result of the etching away of material of the plate between the layers 7 of etch-resistant material on the bottoms of the recesses 4 and the layer on the bottom of the rebate 6. Thus, a trough 12 is formed in the front side of the base plate between the lands 10 and the land 11. This trough and the troughs 9 around the tubes 8 are shown shaded in Fig. 7. Because the flat surfaces of the lands 10 and 11 and the end faces of the tubes 8 forming the jet nozzles are all formed by the one grinding operation, they are all situated in one plane perpendicular to the axes of the jet nozzles.

As can be seen, a jet nozzle plate manufactured by the above method offers the desired advantages, namely, on the one hand the individual jet nozzles consist of free cylindrical tubes which are very effective for the ejection of ink droplets whilst on the other hand the troughs 9 which provide the free space around the individual jet nozzles are surrounded by lands 10 having flat surfaces which are situated in the same plane as the end surfaces of the tubes 8 forming the jet nozzles, so that these lands 10 can be used as supporting surfaces for a capping device when the jet nozzle plate is capped by means of such a device in order to prevent drying of the ink present in the jet nozzles and hence clogging of the jet nozzles. Moreover, the lands 10, being situated at a distance from the tubes 8, also after protection against damage to these comparatively vulnerable tubes.

In the above embodiment, as can be seen in Figure the layers 7 of the lands 10 which surround the jet nozzles 8 form a continuous surface along each row of nozzles. This is due to the fact that the relevant recesses 4 in which these layers were formed open into one another. It has been found that such a formation of the layers 7 is very advantageous since it assists uniform capping of the jet nozzles. As has already been suggested,



However, it is alternatively possible for the recesses 4 to be completely separate from one another. In that case each jet nozzle 8 is surrounded by a separate layer 7, which may be found sufficient for efficient capping of the jet nozzles.

With reference to Fig. 4 it has already been stated that the depth  $t$  of the recesses 4 is preferably chosen to be larger than the thickness  $d$  of the subsequently deposited layer 7. The same result as regards the ultimate form of the jet nozzle plate, however, can also be obtained by making the depth  $t$  smaller than the thickness  $d$ , as shown in Fig. 8. In that case the front of the base plate must be ground down by an amount  $a$  which is again equal to or larger than the thickness  $d$  but smaller than the sum of the thickness  $d$  and the depth  $t$ . Because the depth  $t$  itself is now smaller the grinding may be more critical in this case but less material of the base plate has to be removed, which may also be advantageous in given circumstances. The etching of such a base plate after the grinding has been completed is effected in exactly the same way as in the first embodiment.

In the embodiment shown in Fig. 9 the layers 7 of the lands 10 which surround the jet nozzles 8 form a continuous surface which extends both along each row of nozzles and from row to row. This provides an even better supporting surface for a capping device. To produce this surface the recesses 4 in which the relevant layers 7 are formed are constructed to merge with one another both between the bores 2 in each row of bores and between the rows of bores. A similar result could be obtained by providing a further recess between the two rows of bores 2 in the embodiment described with reference to the Figs. 1 to 7, said further recess connecting the recesses 4 surrounding the bores of one row with the recesses 4 surrounding the bores of the other row.

In the embodiment shown in Fig. 10, a maximum supporting surface for a capping device is obtained. In this embodiment the jet nozzles are surrounded by one continuous land 10 which extends to the edge 5 of the base plate and which forms one continuous surface on the front side of the plate for supporting a capping device. This continuous land is obtained by removing material of the base plate, by further milling, from the whole of the front side of the plate to the same depth as that of the recesses 4, leaving only an annular raised portion around each of the bores 2. The subsequent application of a layer of etch-resistant material to the plate and the grinding and etching processes are carried out in the same way as described above. It has been found that such a jet nozzle plate offers very good results in practice.

In the embodiment of Fig. 11, the base plate 1 is provided with recesses by milling straight grooves in the front side of the plate, the grooves intersecting one another so as to form around each bore 2 a recess in the form of a channel of polygonal shape, in this case rectangular, which channel is spaced from the respective bore to

leave a raised portion of corresponding polygonal shape on the front surface of the base plate surrounding the bore. In Fig. 11 there are three grooves 13, 14 and 15 extending parallel to the two rows of bores 2, the grooves 13 and 15 being located outside the rows of bores and the groove 14 between the rows, and a plurality of grooves 16 extending at right angles to the rows of bores, one groove 16 being located between every two adjacent bores in each row. A rebate 6 is again provided around the edge of the plate 1. This rebate and all the recesses again have the same depth and can readily be formed by means of a side-milling cutter. Outside the two rows of bores 2, further raised portions 17 are left on the front surface of the base plate 1. These portions, however, can also be removed by milling if a maximum supporting surface for a capping device is to be obtained, as in the embodiment shown in Fig. 10. The further steps in the method of manufacturing the jet nozzle plate shown in Fig. 11 are identical to those already described with reference to Figs. 4, 5, 6 and 7 so that all the raised portions on the front surface of the base plate of Fig. 11 are thereby converted into troughs in the finished jet nozzle plate, and all the recesses and the rebate in the front surfaces of the base plate of Fig. 11 are converted into lands on the finished plate.

In this embodiment, the base plate 1 is formed by a raised part of a larger plate 18 in order to facilitate the attachment of the very small jet nozzle plate to the ink-jet printing head. For example, this can be effected by means of screws, for which purpose corresponding holes 19 are provided in the plate 18.

The embodiment of Fig. 12 comprises a base plate similar to that of Fig. 11 but in which the intersecting grooves in the front side of the plate leave raised portions of hexagonal shape surrounding the bores 2. To this end, again three straight grooves 13, 14 and 15 are provided which extend parallel to the two rows of bores 2. Also provided are a plurality of parallel grooves 20 which intersect the grooves 13, 14 and 15 and extend obliquely of the rows of bores 2 in one direction, and a further plurality of parallel grooves 21 which intersect the grooves 13, 14 and 15 and the grooves 20 and which extend obliquely of the rows of bores in the opposite direction, each of the grooves 20 and 21 passing between two adjacent bores in one row and two adjacent bores in the other row. The grooves can again be readily formed by means of side-milling cutters. After completion of the method in the described manner, a jet nozzle plate is obtained whose jet nozzles are formed by projecting tubes each surrounded by a trough which has a hexagonal periphery defined by lands on the front surface of the plate, so that the individual jet nozzles are again uniformly centrically situated in a free manner.

Obviously, further modifications of the described embodiments are feasible, for example, in the choice of the materials used for the

5 manufacture of the base plate and for the etch-resistant layer to be provided thereon. For example, the base plate may alternatively be made of bronze or a chemically etchable synthetic material, or the etch-resistant layer may be chromium.

#### CLAIMS

1. A method of manufacturing a jet nozzle plate for an ink-jet printing head, which plate comprises a jet nozzle having a given internal diameter, wherein a base plate from which the jet nozzle plate is to be formed and which is made of a chemically etchable material is first provided with a bore which extends through the base plate and of which at least a portion that opens out of one side of the plate is cylindrical and has a diameter larger than the desired internal diameter of the ultimate jet nozzle, material is then removed from said one side of the base plate by milling so as to leave on said side of the base plate a portion which adjacently surrounds the bore and is raised with respect to the adjoining portion of said side of the base plate, the whole of the base plate including the wall of the bore is subsequently covered with a layer of etch-resistant material which is chemically deposited on the plate to a thickness equal to half the difference between the diameter of said cylindrical portion of the bore and the desired internal diameter of the ultimate jet nozzle, after which the etch-resistant layer is removed from at least the top of the raised portion on said one side of the base plate by grinding in a plane perpendicular to the axis of the bore to a depth which at least equals the thickness of said layer but which is smaller than the sum of the thickness of the layer and the depth to which material was removed from said one side of the base plate by milling, and finally material of the base plate surrounding the bore and exposed by the grinding is removed by etching to leave the etch-resistant material which was deposited on the wall of said cylindrical portion of the bore projecting as a cylindrical tube from said one side of the base plate to form the jet nozzle, the tube being surrounded by a trough formed in said one side of the base plate by the etching.

2. A method as claimed in Claim 1, wherein the grinding is continued until the etch-resistant layer

50 on that part of said one side of the base plate from which material was removed by milling has been partially ground down.

3. A method as claimed in Claim 1 or 2, wherein the removal of material from said one side of the base plate by milling forms an annular recess in said side of the plate, which recess surrounds and is spaced from the bore in the base plate.

4. A method as claimed in Claim 1 or 2, wherein the removal of material from said one side of the base plate by milling is effected by milling straight grooves in said side of the plate, the grooves intersecting one another so as to form around the bore in the base plate and spaced therefrom a recess in the form of a channel of polygonal shape in said side of the base plate.

5. A method as claimed in Claim 2, or Claim 3 or 4, when read as appendant to Claim 2, wherein the removal of material from said one side of the base plate by milling is carried out to a depth greater than the thickness of the etch-resistant layer subsequently deposited on the base plate.

6. A method as claimed in Claim 3 or 4, or Claim 5 when read as appendant to Claim 3 or 4, wherein a rebate is milled in said one side of the base plate around the edge thereof prior to the deposition of the layer of etch-resistant material, the rebate having the same depth as the recess surrounding the bore in the base plate.

7. A method as claimed in any of the preceding Claims for manufacturing a jet nozzle plate having a plurality of jet nozzles, wherein the base plate is formed with a corresponding plurality of said bores, and wherein around each bore at a distance therefrom a recess is milled in said one side of the base plate so as to leave on this side of the plate a raised portion adjacently surrounding the respective bore, the recesses being formed so as to merge with one another.

8. A method as claimed in Claim 1 or 2, or Claim 5 when read as appendant to Claim 1 or 2, wherein material is removed by milling from the whole of said one side of the base plate except for the portion surrounding the bore.

9. A method of manufacturing a jet nozzle plate, substantially as herein described with reference to Figs. 1 to 7 or any of Figs. 8 to 12.

12. A jet nozzle plate manufactured by the method claimed in any of Claims 1 to 9.